CHAPTER II

Use of Ultraviolet Radiation in the Operating Room: A Historical Review

THE BACTERICIDAL property of sunlight was first described in 1877 by Downes and Blunt. Ten years later, Roux showed (1887) that spores, as well as bacteria, were destroyed by this natural source of radiant energy. In 1903, Barnard and Morgan demonstrated that bactericidal action was limited to the ultraviolet range (3,900 to 136Å).

Over the next three decades, a number of investigators carried out important basic studies on this intriguing and potentially useful lethal effect of ultraviolet radiation on unicellular organisms. The bactericidal range of ultraviolet radiation was further delineated by Newcomer (1917), who narrowed the zone of optimal bactericidal effect to the range of 2,800 to 2,100Å, and later by Ehrismann and Noethling (1932), who found the maximum bactericidal effect to occur at about 2,537Å.

The bactericidal mechanism of ultraviolet radiation was studied and several theories proposed. The work of Bayne-Jones and Van der Lingen (1923) did not confirm an earlier theory that specific wave lengths were lethal for specific bacteria. Burge believed that the photochemical effect was a coagulation of protein within the cell and demonstrated a greater effect on immature than on mature paramecia (1917). Bedford, however, held that the lethal effect was the production of hydrogen peroxide within the irradiated organism (1927). Coblenz reported fully in 1925 on the quantitative aspects of bactericidal radiation, summarizing much of the work of prior investigators.

By 1935, the germicidal quality of ultraviolet radiation was widely recognized, and both industry and the medical profession began to find many applications for it. Various types of ultraviolet lamps were designed and used to sterilize such diverse fluids and solids as drinking water, human plasma, instrument-sterilizing solutions, and toilet seats. Ultraviolet energy was used to inactivate viruses in the preparation of vaccines, to minimize surface bacterial colonization in fish and meat products, and to sterilize the air. It is with the last application that this review is particularly concerned.

As early as 1871, Lister called attention to the air as a source of wound contamination and recommended the use of carbolic acid spray to purify the atmosphere. Although he continued the practice for 17 years, he finally admitted that it was superfluous (Major, 1954). It soon became apparent that many sources were at least as important as air in contaminating operative wounds. At the end of the 19th century, surgical attention was focused on direct contact as the prime mode of wound contamination, as Von Bergmann ushered in the age of asepsis with the introduction of steam sterilization in 1886 and his employment of aseptic technic in 1891. The spectacular results of aseptic surgical methods tended to confirm the importance of contact in the spread of contaminating bacteria; air as a source of operative contamination was neglected. In fact, in 1914, Chapin wrote that a great deal of the theory of airborne infection was unsupported. He emphasized the importance of contamination by contact in the etiology of wound infection and suggested that, as in the epidemiology of typhoid fever and malaria, the theory of airborne surgical wound infection would collapse under the weight of careful epidemiological investigation.

Interest in airborne bacterial contamination was rekindled in 1926 by Meleney and Stevens, who investigated an outbreak of beta-hemolytic streptococcal infections in clean surgical wounds. They discovered that many operating-room personnel were nasal or pharyngeal carriers of beta-hemolytic Streptococcus, and, after isolating a rare serological type of Streptococcus from an infected herniorrhaphy incision, found the identical organism in the nose of an instrument nurse who had been unmasked during the operation. They emphasized the importance of proper masking, as did Walker (1930), Waters (1936), and Davis (1934).

In 1935, Wells, working in the field of respiratory diseases, showed that droplets of moisture from the nasopharynx may remain suspended in air for long periods; he regarded these droplets as important factors in the transmission of respiratory disease (Wells and Wells, 1936). He had previously described the Wells air centrifuge (1933), the first quantitative air-sampling device to measure the intensity of bacterial contamination in the air, and, in 1936, demonstrated that ultraviolet radiation could destroy some species of bacteria suspended in the air. The first ultraviolet lamps to be used in operating rooms were installed in February, 1936, at the Duke University Hospital in Durham, North Carolina, and described later that year by Hart (1936), who noted a decrease in the infection rate in operative wounds and a marked decrease in bacterial contamination of the operating-room air.

Since the separate reports by Hart and Wells, appearing almost simultaneously in 1936, ultraviolet radiation has been used in diverse ways to prevent airborne transmission of infection. Direct and indirect irradiation are distinguished as follows:

direct irradiation denotes the irradiation of the potential recipient of the infection, as well as of the air around him; in the operating room, this entails irradiation of the operative wound as well as of the surrounding surgical team; and

indirect irradiation denotes the irradiation of all or some of the environmental air without irradiating the potential recipient of the infection; this usually involves the irradiation of only a limited portion of the air, e.g., that portion 7 feet above the floor, and has been applied to the control of the transmission of infectious diseases in schools, children's hospitals, and military barracks, and to the reduction of bacterial contamination of the air in bacteriological laboratories and in operating rooms.

Several technics for the indirect ultraviolet irradiation of operating rooms have been described—all of them, by definition, avoiding irradiation of the operative field. Hart experimented with the *barrage* concept of high-intensity irradiation confined to the air in the upper portion of the room (Hart and Nicks, 1961) before adopting direct irradiation, which he has used and advocated since 1936. He concluded that the degree of decontamination of the air obtainable with indirect irradiation, although substantial, fell short of what he could achieve with direct irradiation in the operating room. Browne reported the use of ultraviolet radiation to sterilize the air of the operating room only at night and between operations, with the lamps turned off during operations (1959). High-intensity ultraviolet lamps have also been used in air ducts to reduce the bacterial count in the air as it is introduced into the operating room (Nagy, Mouromseff, and Rixton, 1954). The use of indirect irradiation in the operating room, by avoiding irradiation of the operating team and the operative wound, obviates the wearing of protective equipment by the surgical team and eliminates the possibility of any injurious tissue reaction in the operative wound. It has been shown, however, that the bacterial count of the air in the operating room rises by a factor of from ten to 20 when the room is occupied (Meleney, 1935; Hart, 1938a). Therefore, although irradiation of the empty room or of the incoming (ventilating) air prevents cumulative contamination of the air, it cannot prevent the contamination by the surgical team of the critical site, the air immediately over the operative wound. Indirect irradiation, as used in many operating rooms, is obviously not as effective as direct irradiation in decontaminating the air at the operative site.

Hart has emphasized not only the clinical benefits of ultraviolet radiation, but also the evidence, direct and indirect, that incriminates airborne bacteria as the major cause of wound infection *in clean wounds* and the effectiveness and safety of ultraviolet radiation in eliminating airborne bacteria.

Before 1936, postoperative sepsis was a major problem at Duke University Hospital (Hart, 1941, 1960). Infection rates* in clean wounds were 32.0 per cent in thoracoplasties and radical mastectomies, 8.3 per cent in herniorrhaphies, and 1.8 per cent in thyroidectomies; the mean clean-wound infection rate was over 10 per cent. Seventeen deaths resulted from infections after *clean* operations from 1930 through 1935, for a fatal-infection rate of 1.3 per cent in clean wounds. These infections, especially the most severe ones, tended to cluster in the colder months. The magnitude of the problem may be judged by the virtual shutdown of operating rooms during these outbreaks, with the postponement of all but the most urgent operations until summer. It was in this setting, from 1930 through 1935, that these formidable problems were investigated. Hart enumerated (1941) the following facts to emerge from his study of the infection problem:

1. The skin of the patient and the surgeon's hands "almost never" harbored hemolytic *Staphylococcus aureus* (Hart and Upchurch, 1941);
2. Ninety per cent of the wound infections were caused by staphylococci, usually hemolytic *aureus* (Hart and Upchurch, 1941);
3. The operating-room air was heavily contaminated with Staphylococcus (Hart and Schiebel, 1939);
4. Staphylococcal contamination was present in operating rooms of 40 hospitals in 16 states (Hart, 1938a);
5. Severe staphylococcal infections at Duke University Hospital occurred almost entirely during the colder months, when the operating-room air had an increased staphylococcal content (Hart and Gardner, 1937; Hart and Upchurch, 1941);
6. There was a correlation between the contamination of the operating-room air and the throats of ten members of the operating-room staff whose pharyngeal flora was monitored for a year (Hart and Schiebel, 1939);
7. Streptococcal wound infections accounted for less than 5 per cent of the total infections (Hart and Upchurch, 1941);
8. During the summer, when *Staphylococcus albus* could be cultured from the patients' sweat-laden skin at the operative site, the incidence of postoperative fevers rose, but frank infections were rare and fatal infections absent (Hart, 1940);
9. Bacteria settling on an agar culture plate exposed in an occupied operating room ranged from 50 to 100/hr., but decreased to 0 to 4/hr. when the operating room was empty (Hart and Schiebel, 1939); and
10. Bacterial contamination of the operating-room air varied with the duration of occupancy, the number of occupants, the degree of nose and throat contamination of the occupants, and the activity and talking of the personnel, so that, although the ventilation was efficient in supplying the operating room with clean air, the bacteria emanating from the occupants rapidly contaminated the air (Hart, 1936, 1937) (it was also found that ordinary surgical masks were ineffective in preventing the release of pathogenic bacteria from the nasopharynx of the operating-room personnel into the air).

Focusing on airborne contamination as the primary source of clean-wound infections, Hart instituted a series of measures

* In 469 clean wounds after 1936 but without ultraviolet radiation, as well as 1266 clean wounds before the 1936 installation of ultraviolet lamps.

directed toward its elimination (Hart, 1941, 1960):

1. He installed a ventilating system that ran continuously while the operating room was in use without recirculating air;
2. No visitors were allowed in the operating room;
3. All occupants had to wear masks at all times;
4. Talking was decreased to a minimum;
5. The use of powder on gloves was discontinued;
6. Operating rooms were painted often and washed daily;
7. Major operations were performed early in the day and many elective ones were postponed until summer;
8. Carriers of hemolytic *Staph. aureus* were eliminated from the operating room; and
9. Operative wounds were irrigated with saline at the end of the procedure.

Whether these pre-1936 measures, aimed at controlling airborne infection, were reflected in a decreasing infection rate cannot be ascertained from Hart's published data, which group all unirradiated cases together in tabulations of infection rates. However, he states (1936) that, "despite all these precautions and regulations infections occurred with such frequency that at times we were greatly discouraged." In searching for further methods to solve the problem, Hart turned to ultraviolet irradiation, and in 1936 the first ultraviolet lamps were installed in the operating rooms with the help of the Westinghouse Corporation. The initial installation provided direct irradiation of the operative site by four cold-cathode lamps suspended from the ceiling.

Clinical Studies

In his report (1936) of his initial experiences with this installation, Hart noted that bacterial fallout was reduced markedly, and that 18 thoracoplasties were performed with no infections. The following year he reported (1938b) on 132 thoracoplasties performed with and 110 without ultraviolet irradiation; 36 (32.7%) of those unirradiated became infected, of which four (3.6%) were fatal. There were no deaths from infection in the irradiated-thoracoplasty series, and that series had a total mortality rate less than half that of the unirradiated series. He also noted that drainage of the incision, which had been routine in the unirradiated thoracoplasties, was unnecessary after the introduction of irradiation, and hardly any of the irradiated thoracoplasties were drained. Operations performed under ultraviolet radiation had a lower incidence of postoperative fever, a smoother postoperative course, and better wound healing.

Hart analyzed (1960) the results with 4,382 clean operative wounds* between 1930 and 1941. The ultraviolet-irradiated group had a wound-infection rate of only 0.6 per cent and no fatal infections. The unirradiated group had an infection rate of 11.6 per cent and a fatal-infection rate of 1.1 per cent. It should be pointed out that, although the ultraviolet-irradiated group consisted of patients operated on between 1936 and 1941, the unirradiated group comprised patients operated on before 1936 and a smaller group operated on between 1936 and 1941 (1,313 and 469 cases, respectively). Interestingly enough, in the unirradiated group the fatal-infection rate declined from 1.3 per cent before 1936 to 0.4 per cent after 1936. The over-all incidence of infection in the unirradiated group is not broken down into pre-1936 and post-1936, so one cannot ascertain whether it declined with the fatal-infection rate. Whether the decrease in fatal infections after 1936 *without* the benefit of ultraviolet irradiation represents a changing epidemiological pattern of infection or simply reflects improvement in the therapeutic management of established infection cannot be categorically stated. The decrease does, however, suggest that the comparison of statistics derived from a group (unirradiated) most

* Including 187 re-opened thoracoplasty incisions, ordinarily potentially contaminated.

of whom were operated on before 1936 with those of a group (irradiated) operated on after 1936 may be influenced by important variables other than the introduction of ultraviolet radiation in 1936.

Hart tabulated (1960) the infection rate by type of operation and compared the irradiated and unirradiated groups. For first-stage thoracoplasty and radical mastectomy, the infection rate was 32.0 per cent without irradiation and 0.35 per cent with irradiation; for clean orthopedic procedures, 16.5 per cent without, 0.7 per cent with; for clean neurosurgical procedures, 9.0 per cent without, 0.2 per cent with; for herniorrhaphies, 8.3 per cent without, 0 with; and for thyroidectomies, 1.8 per cent without, 0 with.

In addition to Hart's clinical series, others have reported on low, or at least improved, infection rates following the installation of ultraviolet lamps. Each of these reports is confined to the consideration of clean wounds, and those who compare the results obtained with and without ultraviolet irradiation draw from earlier operative experience for the control (unirradiated) group. In 1940, Overholt and Betts reviewed infections occurring in thoracoplasty wounds. They found that, in 1936, four of 29 (13.8%) thoracoplasties became infected. They altered their skin-closure and wound-dressing technics for their next 261 patients, who developed 17 (6.5%) infections, nine (3.4%) superficial and eight (3.1%) deep. They used direct ultraviolet irradiation of unspecified intensity in their next 411 cases, with the already adopted skin-closure technic; 11 (2.7%) infections occurred, of which two (0.5%) were superficial and nine (2.2%) were deep. They also confirmed Hart's observations (Hart, 1938a), showing that the incidence of postoperative fever was reduced and that the bacterial count on open agar plates was markedly decreased by ultraviolet irradiation.

Woodhall, Neill, and Dratz reported (1949) on 3,019 clean neurosurgical operations performed at Duke University Hospital from 1938 to 1948, using an intensity of 16 μw/cm.^{2} at the operative site instead of the 24 to 30 μw/cm.^{2} recommended by Hart for general surgery. Only 42 infections, 12 severe and one fatal, were encountered in this series, for an infection rate of 1.4 per cent. Although Woodhall *et al.* did not discuss the neurosurgical infection rate at Duke without ultraviolet irradiation, they did describe Penfield's results at Montreal Neurological Institute in neurosurgical procedures. In the period 1942–45, without the use of ultraviolet lamps, Penfield noted 25 infections in 2,275 wounds, a rate of 1.1 per cent. After the adoption of ultraviolet irradiation only ten infections occurred in the next 2,753 wounds during the period 1945–48, for a rate of 0.36 per cent. Woodhall *et al.* considered that ultraviolet irradiation was a valuable tool in achieving neurosurgical asepsis.

After conducting animal and bacteriological experiments (discussed below), Kraissl, Cimiotti, and Meleney used ultraviolet lamps at Presbyterian Hospital in New York City, at considerably lower intensities (1940). Measuring ultraviolet intensity in "clicks per minute" on the Rentschler tungsten-tube radiometer, they initially used an intensity of 5 clicks/min. at the operative site. If their equation of Hart's operative-site intensity (24 to 30 μw/cm.^{2}) to 33 clicks/min. is correct, they were using an intensity of about 4 μw/cm.^{2} They reported that in 52 major clean operations performed with ultraviolet irradiation at that intensity only one minor infection occurred, and concluded that the low intensity, although bactericidal, did not produce the tissue injury that they described at higher intensities. They later used an intensity of 13 clicks/min. (about 10 μw/cm.^{2}) at the operative site, but no clinical results were reported. The latter installation was regulated by an automatic timer to decrease the intensity as the operation progressed and by manual control for adjusting the intensity if the operative procedure was unexpectedly prolonged. They did not note any difference in postoperative temperature in the small series used.

Robertson and Doyle reported on the use of ultraviolet lamps in one operating room of the Hospital for Sick Children in Toronto (1940). The intensity of irradiation, however, was not specified. Although no temperature difference was noted between patients operated on under ultraviolet radiation and the control patients, only one infection occurred in the 41 patients operated on under radiation.

The foregoing clinical reports are summarized in Table 1. (See page 20.)

Atmospheric Bacterial Flora

In addition to reports dealing with the low incidence of infections occurring in ultraviolet-equipped operating rooms, several publications have described the effectiveness of ultraviolet radiation in decreasing the bacterial content of the operating-room air. Hart's earlier investigations on the subject were summarized in a paper with Nicks in 1961. Using the exposed-agar-plate method, they found that 75 to 95 per cent of settling viable bacteria were eliminated by direct ultraviolet irradiation, in contrast to 30 to 50 per cent reduction achieved in their earlier experiments with indirect irradiation. Kraissl, Cimiotti, and Meleney, using an ultraviolet intensity of about 4 μw/cm.^{2} at the operative site, found viable bacteria falling on exposed agar plates at a rate of 0.029 colony/min./plate, compared with 0.25 to 1.90 colonies/min./plate in nonultraviolet operating rooms of the same hospital (1940). Robertson and Doyle investigated the use of direct irradiation of unspecified intensity in an operating room of a pediatric unit (1940). Comparable results were obtained when atmospheric contamination was measured by the settle-plate method, the Wells centrifuge, and an air-filtration sampler. The lower effectiveness of an air-conditioning unit providing eight changes of air per hour, in comparison with that of ultraviolet irradiation, in decreasing the contamination of the operating-room air during 70 operations, was confirmed. The average values obtained by the air-filtration sampler were: 62 bacteria/ft.^{3} of air with neither air conditioning nor irradiation, 26 bacteria/ft.^{3} with air conditioning only, 18 bacteria/ft.^{3} with irradiation only, and 6 bacteria/ft.^{3} with both air conditioning and irradiation. They concluded that, although ultraviolet irradiation was somewhat more effective than air conditioning in reducing the bacterial content of the air, the combination of both was particularly efficacious. Goodman *et al.* found that air conditioning with no filtration actually increased the bacterial content of an empty operating room, but that ultraviolet irradiation was helpful in decreasing it under such conditions (1949).

Injurious Effects of Ultraviolet Radiation

The possibly injurious side effects of ultraviolet radiation have received considerable attention. These include erythema, induction of carcinoma of the skin, keratitis, and other deleterious effects on open wounds. Hart and Sanger stated (1939) that a blond person exposed to 28 to 30 μw/cm.^{2} of ultraviolet radiation developed only a mild erythema in 80 min., but Kraissl and associates found (1940) that at the same intensity slight erythema appeared at six minutes, became marked at nine minutes, and was intense at 15. Rooks produced (1945) an intense but reversible conjunctivitis with about 3,000 μw-sec/cm.^{2}, which would be achieved in two minutes by exposing conjunctiva and cornea to an intensity of 25 μw/cm.^{2} However, both cutaneous and ocular injuries to personnel can be effectively if not conveniently prevented by shielding. Hart used goggles, eyeshades, and cotton caps, which covered the head, ears, and neck of the operating-room personnel, and was careful to protect the patient's eyes from exposure. These precautions eliminated permanent or serious injury to personnel or patients over a period of 23 years of using direct ultraviolet irradiation in the operating rooms at Duke University Hospital (Hart, 1960).

Although the carcinogenic effect of ultraviolet radiation has been demonstrated experimentally, it is apparently confined to wave lengths between 2,900 and 3,341Å. Rusch and co-workers produced carcinoma of the skin of white mice with this range but were unable to produce malignant changes at 2,537Å (the wave length primarily emitted from the ultraviolet lamps used in operating rooms) despite high intensities and repeated exposure (1941).

The effect of ultraviolet radiation on operatively exposed animal tissues was studied by Hart and Sanger (1939). Under sterile conditions, incisions were made exposing subcutaneous tissue and muscle in the abdominal wall, back, and hind legs of rats. The incisions were exposed to 28 to 30 μw/cm.^{2} of radiation for 30 minutes and healed well with less inflammation than the unirradiated controls. Laparotomies were performed in rats exposing intestine and spleen for 30 minutes. At sacrifice seven days later, no differences were noted in the number of adhesions, peritoneal fluid, or appearance of the viscera between the six irradiated rats and the two control rats (exposed only to air). Three gastro-enterostomies and three anastomoses of the sigmoid colon were performed on dogs under ultraviolet radiation with one control dog for each procedure. One of the irradiated dogs developed a fecal fistula after an anastomosis of the colon (the surgeon believed it was not caused by irradiation). The study dealt entirely with clean operative incisions, except for the six gastrointestinal anastomoses performed under ultraviolet radiation.

Kraissl, Cimiotti, and Meleney investigated the effect of ultraviolet energy on the viscera of guinea pigs (1940). Using a high-intensity quartz burner as a source of output over a wide range of the ultraviolet spectrum, they produced gangrene in intestinal loops exposed for 15 minutes. The actual intensity was not specifically stated. They then used a monochromatic source of ultraviolet radiation emitting 88 per cent of its energy at a wave length of 2,537Å, similar to that of the lamps used by Hart. Loops of guinea pig intestine were exposed to an intensity of 33 clicks/min. on the Rentschler radiometer (assumed equal to 24 to 30 μw/cm.^{2}). After exposure for 15 minutes, the incisions were closed and the animals sacrificed at varying intervals. At autopsy the following changes were noted: at two hours after exposure, dilated blood vessels, edema, and extravasated white and red blood cells in the subserosal layers; at 24 hours, edema, blebs, and a tremendous dilation of the vessels; at three days, glandular degeneration of the mucosa; and at seven days, gross fibrous adhesions and extensive glandular destruction in the mucosa (observed histologically). The authors then varied the intensity and duration of exposure, using the production of adhesions in the guinea pig as the criterion of tissue damage. They concluded that the intensities at the operative site, previously recommended, were nearly three times the intensity that the guinea pig intestine would tolerate for 45 minutes. As a result of these experiments, the authors adopted an ultraviolet installation in the operating room that yielded about 4 μw/cm.^{2} at the operative site. This was later increased to about 10 μw/cm.^{2}, a level believed to be effective in controlling airborne bacteria, but safer for the operative wound than the higher intensities recommended by Hart. Although these experiments dealt only with clean incisions, the authors stated that in other experiments no difference was noted in the healing of artificially contaminated wounds. The details and results of the studies on contaminated incisions were not given.

Fraser investigated the effect of ultraviolet radiation on exteriorized loops of guinea pig and rabbit intestine. Although the intensities used were not stated, he described adhesions in two of seven preparations irradiated for 45 to 60 minutes, 20 inches from a Westinghouse Sterilamp tube. However, by increasing the distance from source to tissue and thereby decreasing the intensity, he demonstrated considerable bactericidal effect at distances where no tissue injury was apparent, and he concluded that ultraviolet radiation was safe for exposed tissues at some bactericidal intensities. These precise levels were not defined quantitatively and no contaminated wounds were described in these reports.

A carefully controlled study of the effects of ultraviolet radiation (16 μw/cm.^{2}, 2,537Å) on the exposed canine brain was reported by Odom, Dratz, and Kristoff (1949). Using aseptic technic, the authors reflected a 2.5 × 2.0 cm. dural flap and described the gross and histologic effects. Meningeal vessels were seen to be dilated after 10 minutes of ultraviolet exposure, comparable to 45 minutes of exposure without ultraviolet irradiation. Gross swelling of the brain was noted two hours after irradiation in comparison with three hours without ultraviolet exposure. Microscopic changes started with slight thickening of the arachnoid with dilatation of meningeal vessels and progressed to extravasation of red and white blood cells in the subarachnoid space. Finally, after three hours, subpial hemorrhages and acute swelling or shrinkage of the neurons were described in the irradiated dogs. These changes were similar to those produced by exposing the central nervous system to the air, but occurred considerably sooner in the irradiated brains. The authors concluded that there is no contraindication to the use of ultraviolet radiation in neurosurgery provided 1) that the portion of the brain not being operated on is covered, and 2) that ultraviolet radiation is not used in procedures entailing prolonged exposure of the brain, e.g., locating an epileptic focus or performing an open electro-encephalogram.

In summary, the evidence of beneficial effects of direct ultraviolet irradiation in the operating room has emanated from three areas of study: bacteriology, animal experiments, and clinical reports. The bacteriological studies showed that direct ultraviolet irradiation markedly reduced the bacterial content of operating-room air. The animal experiments were interpreted as demonstrating the safety of irradiating different animal tissues directly with ultraviolet energy at various intensities below 28 μw/cm.^{2} for periods as long as two hours. The several clinical series, although lacking in adequate controls, all showed a remarkable drop in the infection rate in clean operative wounds coincident with the introduction of direct ultraviolet irradiation. The beneficial or harmful effect of ultraviolet radiation on the incidence of infection in contaminated wounds has not been clinically evaluated.

Despite the bacteriological, experimental, and clinical evidence of the efficacy and safety of direct ultraviolet irradiation, this route to antisepsis has not achieved widespread popularity. Although exact statistics are not readily available, estimates emphasize the limited acceptance in the operating room. In 1944, Fraser stated that only three hospitals in Canada were using direct ultraviolet irradiation routinely in their operating rooms. In 1962, Nagy estimated that fewer than ten hospitals, excluding the five involved in the present cooperative study, were using it. A review of the literature in the English language from 1936 through 1961, however, has revealed that all studies suggest that the use of direct ultraviolet irradiation of the operating room reduces the bacterial count of the operating-room air or reduces the surgical infection rate.